A submerged Late Cretaceous podocarpaceous forest, west coast, South Africa

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During mini-submersible dives in De Beers offshore concessions on the middle shelf of Namaqualand, on the west coast of South Africa, a fossil forest was located and sampled. Over an area of 2 km² there are numerous *in situ* and prostrate trunks on a gentle slope, 136–140 m below sea level and about 32 km offshore. Micro-palaeontological dating shows that the sediments are of Coniacian age. The silicified woods have been identified as members of the Podocarpaceae and one new species is described, *Podocarpoxylon jago* Bamford & Stevenson sp. nov. The second species identified is *P. umzambense* Schultze-Motel. These woods are compared with other west coast woods, both onshore and offshore, and the Upper Cretaceous coastal environment is postulated.

Introduction

Palaeontologically, the Upper Cretaceous is a time of great interest: the angiosperms diversified and rose to dominance, and mammals and large vertebrates, such as dinosaurs, were common. The southern continents had separated and the coastal climate of southern Africa was probably humid and seasonally wet.[1–3] Unfortunately, Upper Cretaceous deposits in southern Africa are relatively rare, so the fossil record of this period is meagre. Fossil sites of Late Cretaceous age are restricted to a few kimberlite pipes in the interior and an east coast locality. The Arnot pipe, on the farm Banke in Namaqualand, has preserved lacustrine sediments with a diverse pollen flora and has been radiometrically dated to 71–64 Myr.[4] The pollen of 28 angiosperm families has been identified as well as three types of bisaccate pollen from the gymnosperm family Podocarpaceae. Another kimberlite pipe with fossiliferous lacustrine deposits is Stompoor in Bushmanland,[5] which has been tentatively dated as mid-Senonian. It has yielded numerous fossil frogs, dinosaur vertebrae and fragmentary plant remains of angiosperms and Araucariaceae, a conifer family that no longer occurs naturally in southern Africa. Some offshore deposits west of Cape Town described by McLachlan and Pieterse,[6] representing the entire Cretaceous, contain three types of podocarpaceous pollen, as well as an increasing diversity of angiosperm pollen going up the sequence. On the southeast coast in Pondoland, fossil woods of angiosperms and gymnosperms, including the Podocarpaceae, have been described.[7,8]

Lower Cretaceous woods from the west coast have been described by Bamford and Corbett[9,10] from onshore and offshore deposits, but here we give the first description of fossil woods from the Upper Cretaceous in this region. Furthermore, an extensive *in situ* forest has been preserved 136–140 m below sea level, some 32 km from the present-day shoreline. Together with complementary micropalaeontological and seismic stratigraphic analysis, this observation provides clear evidence of a Late Cretaceous coastal plain succession that is now preserved as a sea floor outcrop.[11,12] The age of the outcrop is Coniacian (middle of the Late Cretaceous 88–83 Myr);[11,12] the Coniacian succession here is typified by fluvial-to-marine deposition repeated on at least a 4th-order cyclicity (~200 kyr).

Materials and methods

De Beers Marine geologists have been constructing a regional geological framework for the west coast offshore concessions over the past few years. They have produced a fairly detailed map using seismic data, side-scan sonar, sedimentological and micropalaeontological data. The map shows major Cretaceous unconformities, which have been uplifted, eroded and exposed to sea floor; the unconformities show up as prominent ridges parallel to the coast. During those surveys, side-scan sonar interpretations revealed the presence of a unique sea floor texture, comprising a complex set of lineations situated about 32 km off the present-day Buffels River system (Fig. 1).

This area was subsequently investigated using the Jago mini-submersible. Seabed visuals and grab-sampling from the dive revealed the presence of a fossil forest, some 2 km² in extent. Only five pieces of fossil wood were collected, as there are limits to the size of object that the Jago can pick up with its grab claw, and that will fit into the sample basket.

Petrographic thin sections were made in the usual way, in the transverse, radial longitudinal and tangential longitudinal directions of the silicified wood. The sections were hand-ground to a thickness of approximately 25 μm and studied and photographed under a Zeiss Axioskop microscope. Measurements were taken of a minimum of 25 cells or pits, and averaged. For the tracheid diameters, the minimum and maximum sizes are also given. The woods have been compared with all the relevant published taxa, as well as the fossil woods already collected from southern Africa that are in the Bernard Price Institute collections.

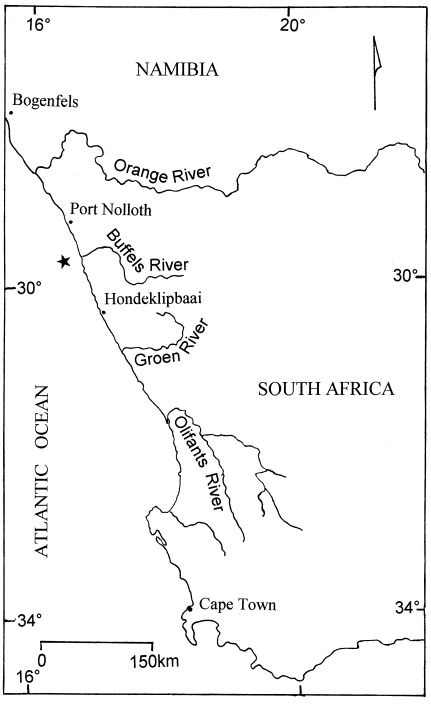

Fig. 1. Map of the west coast of South Africa. Fossil forest locality indicated by a star.

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Description of wood

Two samples were well preserved and are described in detail. One of these is sufficiently different from previously published descriptions of woods to merit new species status. The other woods are described briefly.

Class: Pinopsida
Order: Coniferales
Family: Podocarpaceae Endl.
Genus: *Podocarpoxylon* Gothan 1905
Type species: *P. juniperoides* Gothan in Gagel 1907

***Podocarpoxylon jago* Bamford & Stevenson sp. nov.**

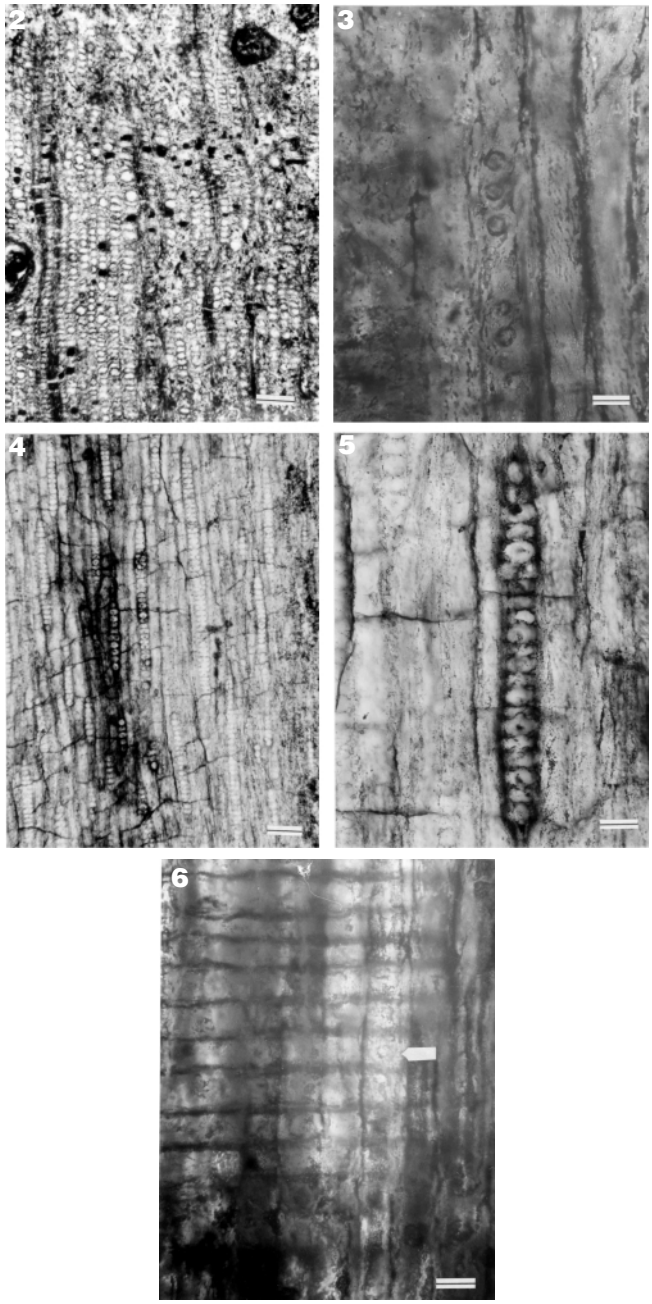
Catalogue number of the holotype: BP/16/722.
Locality: Namaqualand continental shelf, 32 km offshore, between Port Nolloth and Kleinzee. 27°41′S, 14°38′E and 27°39′S, 35°31′E.
Stratigraphy: Coniacian.
Collector: I.R. Stevenson.
Figures: 2–6.
Etymology: Name of the mini-submersible that retrieved the samples from the sea floor.

The piece of wood is silicified and grey, with rather patchy preservation. It is 13 × 8 × 29 cm in size, but was once a large tree with a diameter greater than 50 cm. There is no central pith. Growth rings are absent on the slide, but dark bands are just distinguishable on the specimen, ranging in width from 1–2.5 mm. As there are no corresponding cellular features, these bands are most probably 'colour rings' formed by the migration of iron oxides through the silicified wood. The tracheids are round to oval in transverse section, with large empty lumens, and are somewhat radially compressed (Fig. 2). The mean tangential diameter of early-wood tracheids is 45 μm (range 40–52 μm) and mean radial diameter is 33 μm (range 30–35 μm). The total thickness of adjacent tracheid walls is 3–7 μm. The bordered pits occur on the radial walls only and are exclusively uniseriate, separate and 15 μm in diameter with an aperture of 5 μm (Fig. 3). The distribution of the tracheid pits is very variable; this could be an artefact of preservation or minor non-alignment of the tracheids, so that the section transects only a few pits. In fact, tracheid pits are rare and do not form long columns as is common in many coniferous woods.

Rays are homogeneous and uniseriate but often have a biseriate portion of only one pair of cells, rarely three or four pairs of cells (Figs 4, 5). The height ranges from 6–42 cells with an average of 28 cells. There are six rays per mm. In tangential longitudinal section (TLS) the individual ray cells are relatively wide and closely packed. They measure 20–25 μm high by 46–54 μm wide in TLS, which means that the horizontal dimension of the cell is twice that of its vertical height, whereas ray cells in conifer woods are usually higher than wide. The section is a true tangential one and so the width of the ray cells has not been exaggerated. Ray cell walls are thin and smooth and the cross-field pits are narrowly bordered with a vertical to slightly oblique aperture, single and small, 7.5 μm in diameter (Fig. 6). Not all cross-fields have pits. In radial longitudinal section (RLS) the ray cells are 25 μm high and 100–125 μm long. No axial parenchyma or canals were seen. A dark deposit, possibly resin, occurs in a few of the tracheids and ray cells.

Diagnosis

Secondary xylem of coniferous wood with bordered pits on the radial walls of the tracheids exclusively uniseriate, separate and with an average diameter of 15 μm. Cross-field pits small and single with a narrow border (podocarpoid). Axial parenchyma, spiral thickening and canals absent. Rays uniseriate with low biseriate portions of usually one or two cells only, high to very high, numerous, and cells in the tangential section approximately twice as wide as high, sometimes with resin deposits. Ray cell walls thin and unpitted (except cross-fields).



Figs 2–6. *Podocarpoxylon jago* Bamford & Stevenson sp. nov. BP/16/726. **2**, Transverse section (TS) showing the early-wood tracheids. Dark cells contain resin. Scale bar = 150 µm; **3**, radial longitudinal section (RLS) showing uniseriate, separate bordered pitting on the radial walls of the tracheids. Scale bar = 30 µm; **4**, tangential longitudinal section (TLS) showing the high, uniseriate rays. Scale bar = 150 µm; **5**, TLS with one ray enlarged to show the wide cells. Scale bar = 50 µm; **6**, RLS with round to oval, narrowly bordered to simple cross-field pits. Scale bar = 20 µm.

Discussion

This wood is typically podocarpoid with the round and often well-spaced tracheid pits on the radial walls and podocarpoid cross-field pitting. The wood differs from that of other species of *Podocarpoxylon* in that the ray cells are very broad in tangential